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rine station at Roscoff and its enthusiastic master long continue the work which has had so much influence on French science, and may its liberality and hospitality be imitated and fostered in other lands by other people.

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## ON THE PERMIAN FORMATION OF TEXAS.

BY CHARLES A. WHITE.

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DURING the past ten years Prof. E. D. Cope has from time to time published descriptions and figures of vertebrate remains from Texas which he referred to the Permian,<sup>2</sup> although other authors have generally regarded the formation from which the fossils were obtained as of Triassic age.

A year ago Mr. W. F. Cummins, Assistant State Geologist of Texas, who had collected a large part of the vertebrate fossils just referred to, gave me a small suite of invertebrate fossils which he had collected from the same formation with the vertebrates. I found these fossils to possess so much interest that I afterward, in company with Mr. Cummins, visited the region in question and made collections from, and observations upon, the formation containing them.

Thirty-two species of invertebrates were collected, about one-half of which were readily recognized as well-known Coal-measure species, but a few of them were new, among which are two belonging to mesozoic types. It is this paleontological feature, in connection with important correlated facts, that especially excited my interest in the formation from which the fossils were obtained.

Although I have personally examined a considerable portion of the region within which this formation occurs, I am indebted to

<sup>1</sup> This article is an abstract from a bulletin of the Survey now in course of preparation.

<sup>2</sup> For his summary of North American Permian vertebrates, including this Texan fauna, together with references to the places of publication, see *Trans. Am. Philos. Soc.* Vol. XVI, pp. 285-288.

Mr. Cummins for a large part of the facts upon which the following description of it is based. This is especially true with regard to the extent of the area which it occupies.

In Texas this formation occupies an area, many hundred square miles in extent, which constitutes the western part of the southern extremity of the great central paleozoic region of the continent. The southern boundary of this area is not now definitely known, but it lies at least as far south as the Concho river. Its eastern boundary may be approximately designated as extending from Red river to the Colorado through Clay, Young, Shackelford, Callahan and Runnels counties; and its western border as extending from the Canadian river to the Concho through Hemphill, Wheeler, Donley, Briscoe, Motley, Dickens, Garza, Borden and Howard counties. The formation is known to extend northward far within the Indian Territory, but in this article special reference is made only to that portion of it which is found in Texas; and the description which is herein given is drawn mainly from observations made in Baylor, Archer and other contiguous counties.

This formation rests directly and conformably upon another series of strata in which a characteristic Coal-measure fauna prevails but which is not now known to include any fossils of mesozoic types, if we except the *Ammonites parkeri* of Heilprin, which he states was obtained from Carboniferous strata in Wise county.<sup>3</sup> Notwithstanding the mesozoic character of a part of the molluscan fauna of the upper formation, the preponderance of evidence makes it necessary to regard it as belonging to the great Carboniferous system, and as constituting an upper member of it. For these and other reasons yet to be stated I have little or no hesitancy in designating this Texan formation as Permian, as Prof. Cope has done; but I shall briefly discuss in following paragraphs the propriety of the use of that name for all of the North American strata to which it has been applied.

The Texas Permian is distinguishable in general aspect and in lithological character from the formation which underlies it and which represents at least a large part of the Coal-measure series as the latter is known in the Upper Mississippi Valley. And yet the Permian strata blend so gradually with those of the Coal-measures beneath, and with the gypsum-bearing beds, above that it is difficult to designate a plane of demarkation in either case.

<sup>3</sup> Proc. Acad. Nat. Sci. Philad., Vol, XXXVI, pp. 53-55.

The strata of the Texas Permian consist of materials which are somewhat difficult to describe, but they may be stated in a general way to consist mainly of sandstones and sandy and clayey shales, which are sometimes calcareous, with a few layers of impure limestone, besides one somewhat important limestone horizon. A common characteristic of many of the layers is the presence of an abundance of small, hard, rough concretions, which usually become separated and accumulate upon weathered surfaces as the imbedding clayey material is removed by erosion. But what strongly impresses the general observer is the prevailing reddish color of the formation, which is due to the prevalence of red oxide of iron in most of its component materials. During the rainy season the waters of the streams which traverse the formation are reddened by the abundant ferruginous, clayey sediment, which they obtain by erosion.

The stratification is generally more or less regular, but in the district here especially referred to it contains comparatively few compact, evenly-bedded strata. Therefore the formation having been, in this district, only slightly disturbed since its deposition, few striking features in the landscape occur. That is, the district is a comparatively plain country, the surface of which, in the general absence of forests, is diversified only by shallow valleys of erosion and low hills of circumdenudation, with here and there a hill or bluff of like origin which reaches a height of one or two hundred feet above the general level. From the top of these higher elevations extended views are to be obtained, which are of much advantage in the study of geological structure in that region.

Because of the slight disturbance which the Permian strata have suffered in the district referred to, and the general absence of bold escarpments, it is difficult to arrive at an accurate measurement of its thickness, but it is approximately estimated at 1,000 feet. By distant view from the hills before mentioned, a general, gentle dip to the westward of the whole formation is plainly discernable. It is from a succession of such observations of the dip, together with measurements of the thickness of exposed strata and estimates of that of the unexposed, that the foregoing estimate of the full thickness of the formation has been made.

A list of all the species of invertebrate fossils that have been discovered in the Permian of Texas is given on a following page. Prof. Cope's list of vertebrate species, already referred to, shows

that the same formation has furnished 10 species of fishes, 11 of batrachians and 33 of reptiles; 54 species in all.

The full thickness of the Coal-measure series in Texas is not yet known, its base not having been observed; but the portion that has been examined reaches an estimated thickness of 1800 feet. The strata are generally somewhat evenly bedded, and consist of bluish and gray limestones, gray and ferruginous sandstones, bluish and carbonaceous shales and clays; and several coal horizons are now known in the series there.<sup>4</sup> These strata have furnished at numerous localities, and in greater or less abundance, such characteristic Coal-measure invertebrates as the following: *Terebratula bovidens* Morton, *Spirifer cameratus* Morton, *Athyris subtilita* Hall, *Productus cora* d'Orb., *P. nebrascensis* Owen, *P. costatus* Sowerby, *P. semireticulatus* Martin, *Hemipronites crassus* Meek and Hayden, *Myalina subquadrata* Shumard, *Allorisma subcuneata* M. and H., *Nuculana bellistriata* Stevens, *Pleurotomaria tabulata* Conrad, *Bellerophon carbonarius* Cox, *B. percarinatus* Conrad, and *Macrocheilus ponderosus* Swallow. Many other species also have been found associated with those which have been just named, but the latter are quite sufficient to characterize the strata containing them as belonging to the Coal-measure series. No attempt has been made to subdivide the Coal-measure series of Texas into upper, middle, and lower portions as has been done in the Upper Mississippi Valley, and they are probably not capable of such a subdivision in this southern region. The Lower or Subcarboniferous portion of the system has also not been recognized in Texas.

Along the western boundary of the Texas Permian, as it has been indicated in a previous paragraph, a series of strata, about 250 feet in maximum thickness, now generally known as the "gypsum-bearing beds" and thought by many to be of Triassic age, rests conformably upon the Permian. In general aspect, in a prevailing reddish color, and in general lithological character, except in the prevalence of gypsum in many of the layers and the somewhat greater prevalence of clayey material, these overlying beds resemble the Permian strata upon which they rest. With only one known exception these gypsum bearing beds have furnished no fossils. The exception referred to is the discovery by Mr. Cummins in Hardiman county, in an upper stratum of those beds, of a thin magnesian layer containing

<sup>4</sup> Mr. Cummins informs me in an unpublished letter that he has distinguished no less than nine coal horizons there.

numerous casts of a species of *Pleurophorus*. This being a characteristic genus among Permian molluscan faunas and a prevailing form in the Permian strata beneath the gypsum bearing beds, the question is suggested whether the latter ought not to be regarded as constituting an upper portion of the Permian. If these beds are not separable from the Permian, it seems to be doubtful whether the Trias has any representation in Texas.

It will be seen from the foregoing remarks that in the part of northern Texas to which special reference has been made, there is a great conformable series of strata having a slight general dip to the westward, its base being covered from view by mesozoic and later formations. The estimated thickness of this older series, so far as it is exposed to view, is 3050 feet. The lower 1800 feet, together with an unknown thickness beneath, is referred to the Coal-measures. The next overlying 1000 feet of strata are designated as Permian; and the upper 250 feet of the series is doubtfully referred to the Trias, although as already intimated there seem to be reasons for regarding the latter beds as constituting the upper part of the Permian. Cretaceous strata rest unconformably, and with a contrary dip, upon the earlier eastern portion of this series; while upon the later western portion they rest with apparent conformity; although their real conformity there may be properly questioned because the Jura seems to be entirely wanting, and at most the Trias is only slightly developed.

As already stated, the Cretaceous strata appear to rest conformably upon the gypsum-bearing beds; and the latter beds lie quite conformably with the Permian and Coal-measures beneath, all having a westward dip. On the contrary, all the beds from the Dinosaur Sands, which are regarded as the lowermost Cretaceous formation in Texas, to the Tertiary inclusive, have an easterly dip and seem to lie unconformably with the Coal-measures and Permian. It is not certain, however, that the Carboniferous and older strata do not dip to the eastward beneath the Cretaceous strata, forming an anticlinal axis. Having thus shown the stratigraphical relation of the Texas Permian with the other formations, the following remarks will be confined to the Permian alone.

The following descriptive section of the Texas Permian is taken from Mr. Cummins' field notes, but it has been in large part verified by my own personal observation. The different members of this section, which are indicated by consecutive numbers, are not

distinctly definable from one another, but the section is presented in this form for convenience in making reference to the respective horizons at which collections of fossils have been made.

DESCRIPTIVE SECTION OF THE PERMIAN OF TEXAS.

1. Reddish and mottled sandy clays, with occasional layers of sandstone.

2. Variously colored clayey and sandy concretionary strata, with a few irregular layers of impure concretionary limestone ; embracing near its middle a somewhat persistent stratum of limestone of greyish blue color.

3. Sandstones alternating with clayey and sandy concretionary layers and a few fine grained silicious layers.

4. Reddish and buff colored clayey and sandy shales with occasional layers of sandstone.

5. Sandstones and sandy shales ; with beds of reddish sandy clay ; passing gradually into the Coal-measures beneath.

Vertebrate remains, which Prof. Cope confidently refers to the Permian, occur at numerous localities and at many horizons from the base to the top of this section ; but invertebrate remains have hitherto been discovered only in strata which are included in Nos. 2 and 3 respectively of that section. The lowermost known horizon of invertebrates is about 400 feet above the base of the series, and the uppermost is about as much below the top of the same. That is, the invertebrate fossils described and figured in this article come from the middle 200 feet in thickness of the Permian series as it has just been defined.

The localities at which these fossils were obtained, only three in number, are in Baylor and Archer counties ; and as the country is still an unsettled one, they can be designated only in an indefinite way. The first of these localities, which is in the northwestern corner of Archer county, will be designated as "Camp Creek." The second is in Baylor county, near the middle of its eastern boundary line, and will be designated as "Godwin Creek." The third is in the northeastern part of Baylor county, near where the old military road, constructed by General Van Dorn, crossed the Big Wichita river. This locality will be briefly designated as the "Military crossing of the Big Wichita." The strata of the two first mentioned localities occur in No. 3 of the foregoing descriptive section of the Permian, and the last named one, in No. 2.

The following is a list of all the invertebrate species which are now known to have been found in the Texas Permian, all of which are discussed on following pages. The list is presented in tabular form for the purpose of giving a synoptical view of the fauna, so far as it is at present known, and also to indicate the localities at which the respective species have been discovered, as well as their inter-association there. As to the latter condition, it is proper to state that specimens of all the species found at the locality which is indicated as the Military Crossing, were collected by myself from a single stratum, where they were found commingled in such a manner as to leave no doubt as to their having been all members of one and the same contemporaneous fauna. Specimens of the greater part of the other species were also collected by me at the localities indicated.

LIST OF SPECIES.

	Camp Creek.	Godwin Creek.	Military Crossing.
1. <i>Goniatites baylorensis</i> n. s.....			X
2. <i>Ptychites cumminsi</i> n. s.....			X
3. <i>Medlicottia copei</i> n. s.....			X
4. <i>Popanoceras walcotti</i> n. s.....			X
5. <i>Orthoceras rushensis</i> McChesney?.....			X
6. <i>Nautilus winslowi</i> Meek and Worthen.....			X
7. <i>N. occidentalis</i> Swallow.....			X
8. <i>N.</i> ————?.....			X
9. <i>N.</i> ————?.....		X	
10. <i>N.</i> ————?.....			X
11. <i>N.</i> ( <i>Endolobus</i> ) ————?.....			X
12. <i>Naticopsis remex</i> White.....		X	X
13. <i>N. shumardi</i> McChesney?.....		X	
14. <i>Euomphalus subquadratus</i> M & W.....			X
15. <i>E.</i> ————?.....			X
16. <i>Murchisonia</i> ————?.....		X	X
17. <i>Patella</i> ————?.....		X	
18. <i>Bellerophon crassus</i> M & W.....		X	X
19. <i>B. montfortianus</i> Norwood & Pratten.....		X	
20. <i>B.</i> ————?.....			X
21. <i>Sedgwickia topekaensis</i> Shumard sp.....		X	
22. <i>Pleurophorus</i> ————?.....		X	
23. <i>Clidophorus occidentalis</i> Geinitz.....		X	
24. <i>Yoldia subscitula</i> Meek & Hayden.....		X	
25. <i>Myalina permiana</i> Swallow.....	X	X	X
26. <i>M. aviculoides</i> M & H.....		X	
27. <i>M. perattenuata</i> M & H.....	X	X	X



28. <i>Gervillia longa</i> Geinitz.....	X	
29. <i>Aviculopecten occidentalis</i> Shumard.....		X
30. <i>Syringopora</i> —————?.....	X	X
31. <i>Spirorbis</i> —————?.....		X
32. <i>Cythere nebrascensis</i> Geinitz.....		X

## SUMMARY.

Mollusca.	{ Cephalopoda.....	11 species.	
	{ Gastropoda.....	9	"
	{ Conchifera.....	9	"
Articulata,	{ Vermes.....	1	"
	{ Crustacea.....	1	"
Radiata....	Polypi.....	1	"
Total,		32	"

By reference to the foregoing list of species, and especially to the summary at the foot of the list, it will be seen that the invertebrate collections which have hitherto been made from the Permian formation of Texas, do not represent a fauna in its usual proportions, as regards the classes and families to which the species respectively belong. This is especially true when we compare these collections with Permian faunas already known in other regions. For example, it will be seen that the Cephalopoda are in unusually large proportion, that the Brachiopoda and Polyzoa are absent, and that the Polypi are represented by only a single species. In short, it is plain that the invertebrate fauna which existed during the period in which the Texas Permian was deposited, and in the same, or in contiguous waters, is imperfectly and disproportionately represented by these collections.

Some of the causes of the imperfection and disproportion referred to, are too plainly apparent to need extended comment, and others are suggested by the lithological and stratigraphical character of the formation in which the remains are found. Besides the inevitable causes of imperfect representation of extinct faunas by their remains, a conspicuous reason for the imperfection of these collections is that the formation has yet been carefully examined in only a small part of the large region which it is known to occupy, and an exhaustive search for invertebrate fossils has yet been made at only a few of the localities which have been visited by competent collectors.

Again, there are few strata entering into the composition of the Texas Permian where it has been examined, the character of which indicates that they successively formed the bottom of waters where at least a large proportion of then existing invertebrates

could not have found a congenial habitat. That is, sandy and other silicious strata, as has already been shown, prevail in this formation, while calcareous strata are comparatively rare. It is true that certain families, especially of the Mollusca, find a silicious, sandy bottom, such as the material of most of those strata doubtless formed, more congenial than a muddy or calcareous one; but to far the greater part of all invertebrate faunas the latter kind of bottom, other conditions being favorable, is much more congenial. In short the lithological character of a formation often presents obvious reasons not only for the comparative paucity of all invertebrate fossils in its strata, but even for the absence of representatives of certain families which we have every reason to suppose existed when they were deposited, but in other, not far distant places, and in more congenial waters.

But these collections, imperfect as they are, present subjects for consideration which are of far greater interest than that which attaches to a mere addition to our knowledge of a few of the forms which constituted the fauna of any given epoch or period. Such, for example, as the relation which the fauna of one period in a given region bore to faunas which were presumably contemporaneous with it, and to those of the periods which immediately preceeded and followed it; and the indication which these fossils give as to the geological age of the strata containing them.

Three of the Cephalopod species, the names of which are given in the foregoing list, are represented on the accompanying plate, and brief descriptions of them follow.

*Ptychites cumminsi* n. s. Plate I figs. 4, 5, 6, 7 and 8.

Shell compressed-subglobose, volutions deeply embracing, umbilici small; septa numerous and complex, the suture line as represented by fig. 8.

*Medlicottia copei* n. s. Plate I, figs. 1, 2 and 3.

Shell thinly discoid, periphery narrow, medially grooved, umbilici small; volutions deeply embracing; septal suture as shown by fig. 3.

*Popanoceras walcotti* n. s. Plate I, figs. 9, 10 and 11.

Shell discoid; periphery deeply embracing; umbilici minute; surface marked by slightly sinuous radiating lines or indefinite ridges; septal suture as shown by fig. 11.

The other species which is definitely recognized as new is a *Goniatites* whose general character is not unlike that of known Carbon-

iferous species. The *Ptychites* and *Popanoceras* may be properly regarded as of mesozoic type, such as might be expected to occur in Triassic strata. The *Medlicottia* is the first species of the genus to be discovered on this continent, and has been usually regarded as indicating the later Carboniferous, or Permian age, of the strata containing the genus.

## EXPLANATION OF PLATE I.

### MEDLICOTTIA COPEL.

- Fig. 1. Lateral view.  
 " 2. Outline showing transverse section of volutions.  
 " 3. Suture line.

### PTYCHITES CUMMINSI.

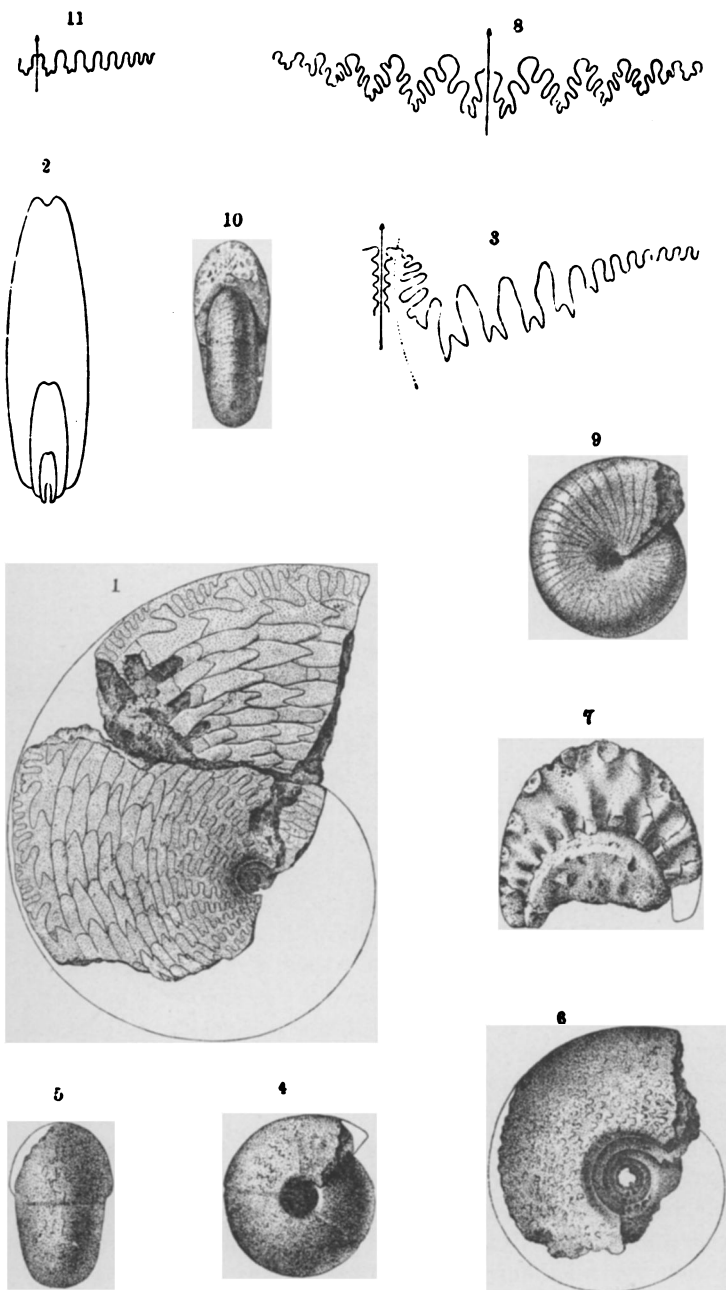
- " 4. Lateral view of a small example.  
 " 5. Peripheral view of the same.  
 " 6. Lateral view of a larger example.  
 " 7. View of a septum of a larger example.  
 " 8. Suture line of the same.

### POPANOCERAS WALCOTTI.

- " 9. Lateral view of a small example.  
 " 10. Peripheral view of the same.  
 " 11. Suture line.

All the figures are a little less than natural size.

It will be seen from the foregoing descriptions and notes, that of the 32 species of invertebrates which are represented in the collections from the Texas Permian, only four of them are recognized as new, all of which are cephalopods, and all belong to the Ammonoidea. The others have either been previously described and published, or their specific identity with published forms is in doubt because of their imperfection, either of the specimens in hand, or of the manner of publication of the species which they probably represent. Fifteen of these Texan species are satisfactorily recognized as having been previously published, a part of which have been by some authors referred to the Permian, but the Coal-measure age of the remainder has never been questioned. Some authors also assert that not only all of the fifteen species just mentioned, but all North American invertebrate species which have ever been referred to the Permian, are really members of the fauna which characterizes the Coal-measure period. Indeed, so generally has this view prevailed during the last twenty years, that if the four new cephalopods before mentioned were not present in the Texan



Permian Cephalopoda.

collections, no American palæontologist who is familiar with the Coal-measure fauna, would probably have hesitated to refer them all to that period.

It is doubtless true that because so large a proportion of the invertebrate species, which have been obtained from reputed Permian strata in North America, occur also in characteristic Coal-measure strata, no satisfactory separation of them into two groups has hitherto been practicable upon the evidence of invertebrate fossils; and stratigraphical evidence has hitherto been unsatisfactory also. The collections, however, which are represented by the foregoing list and descriptions, although consisting mainly of Carboniferous forms, contain at least two types which are so generally regarded as indicating the Mesozoic age of the strata containing them, that if they alone, and without any statement of correlated facts, had been submitted to any paleontologist, he would not have been warranted in referring them to an earlier period than the Trias, if he had followed the usually accepted standard of reference. These two forms have been described on preceding pages, under the names of *Ptychites cumminsi* and *Popanoceras walcotti* respectively; and with the exception of the *Ammonites Parkeri*<sup>5</sup> of Heilprin, also from Texas, similar types have never been found associated with recognized Carboniferous species in North America.

This, however, is by no means the first, nor the most important discovery of the commingling of Mesozoic and Paleozoic types in such a manner as to indicate that they all lived contemporaneously, and were members of one and the same fauna. The remarkable discovery by Professor Waagen, in India, of<sup>6</sup> many molluscan species belonging to mesozoic types associated with a characteristic Carboniferous fauna is well known. It is also well known that mesozoic characters are recognizable among certain of the Carboniferous and Permian cephalopods of Russia and Armenia, as well as of certain parts of Europe.

The special interest which these Texan collections possess lies, first, in the presence of the two cephalopods of mesozoic type as members of an invertebrate fauna composed otherwise of paleozoic types; and second, in the association of this invertebrate fauna with a vertebrate fauna composed mainly of Permian types, as de-

<sup>5</sup> Proc. Acad. Nat. Sci. Phila. 1884, vol. XXXVI, p. 53.

<sup>6</sup> See Paleontologia Indica Series XIII; Salt Range Fossils.

terminated by Professor Cope, and in the known superposition of the formation containing these faunas upon characteristic Coal-measure strata. The first point of interest relates to the interdelimitation of the Mesozoic and Palæozoic; and the second, to the assumed Permian age of the Texan formation from which the collections referred to were made.

The biological interdelimitation of the Mesozoic and Palæozoic ages in geological history has long been regarded as clearly recognizable in all parts of the world. While it was well known that a considerable number of generic forms, especially of the invertebrates, respectively occur in strata of both ages, palæontologists have generally regarded it as a fundamental fact that certain orders, families, and even genera, which possess certain characteristics of structure and form, were rigidly confined to each age respectively. That is, they believed that the types which fall into the one category all ceased to exist at the close of the Palæozoic age, and that no member of the other category began its existence before the opening of the Mesozoic age. The presence of remains belonging to either the one or the other of these categories was therefore regarded as affording unquestionable proof of the geological age of the strata containing them. Attempts were made to explain the first discoveries of the commingling of earlier and later types in one and the same stratum, by assuming that the specimens showing the earlier types of structure were derived in an already fossil condition from pre-existing strata in the process of their destruction by which the materials for new strata were produced.

However unphilosophical those views concerning the chronological restriction of certain types may appear in the light of modern biology, it is not to be denied that until within comparatively few years paleontological observations in the field seemed, as a rule, to favor them. These later discoveries, important instances of which have been referred to, show conclusively that animals belonging to both the categories which have just been indicated lived contemporaneously. It furthermore appears that some of those which have been regarded as exclusively mesozoic in character began their existence while yet Palæozoic forms were far in the ascendant; and also that many Palæozoic types survived their earlier associates and lived in association with Mesozoic faunas. As I shall discuss this subject in another publication, it need not receive further consideration here; but I offer in following paragraphs some general re-

marks upon the reputed North American Permian, in the course of which reference will be made to the bearing which the presence of Mesozoic types among the Texan Permian fossils has upon the question of the geological age of the strata containing them.

From time to time during the past thirty years there have been discussions among geologists as to whether there is in North America any true equivalent of the Permian formation of Europe. Some writers have been uncompromising in their advocacy of the affirmative side of this question, and others have been equally positive in asserting the negative. Much of this difference of opinion has arisen from imperfect knowledge of essential facts, and much from want of a clear definition by the respective writers as to what they have regarded as constituting equivalency in this case. Although much addition has within the past few years been made to our knowledge of facts bearing upon this question, and it is evident that clearer views upon it are now generally held than formerly prevailed, it is too much to expect that the views of all geologists should even now fully agree. The following statement of the present condition of this question, as the writer understands it, is presented that the reader may understand more clearly his views, and the reasons for the conclusions and opinions which are expressed in this article.

In Europe the Carboniferous system is understood to be divided into three great groups, namely, the Lower Carboniferous, the Coal-measures and the Permian, which are definable from one another, not only by palæontological, but by stratigraphical characteristics. In North America, the great Carboniferous system is quite as largely developed as in Europe. The Lower Carboniferous and Coal-measure groups are, upon both stratigraphical and palæontological grounds, as clearly recognizable and distinguishable from each other, in some parts of this continent, as they are in Europe, but the Permian has hitherto had no such undisputed recognition. Therefore, the question now to be considered is whether the Permian of Europe has really an equivalent anywhere in North America; and if so, how that equivalency is recognizable.

There are seven principal regions in North America within which strata occur that have been by different authors referred to the Permian. These are (1) southwestern Pennsylvania and northern West Virginia; (2) Prince Edwards Island; (3) eastern Illinois;

(4) northeastern Kansas and southeastern Nebraska ; (5) South Park, Colorado ; (6) isolated portions of New Mexico, Arizona, Utah and Western Colorado, and (7) northern Texas and the adjacent part of Indian Territory.

In all these cases there seems to be no room for doubt that the strata in question are not older than the Upper Coal-measures, as that formation is distinguishable in North America, but aside from their evidently high position in the Carboniferous system, their recognition as Permian has been based upon different kinds of evidence in each case. In the first and second mentioned cases it was based wholly upon plant remains ; in the third, upon vertebrate remains alone ; in the fourth, upon invertebrate remains ; in the fifth, upon plants and insects,<sup>7</sup> and in the sixth, mainly upon stratigraphical position. The evidence in favor of the recognition of the strata, as constituting a separate formation in the seventh case, is presented in this article.

Two general ideas seem to have prevailed respectively in the minds of those who have considered the question of the recognition of the Permian in North America. On the one hand, the discovery on this continent of remains belonging to generic or other types of vertebrate, invertebrate, or plant life, which are respectively similar to forms found in the European Permian, have been regarded by some authors as surely indicating in each separate case the Permian age of the strata containing them, even in the absence of, or without regard to, correlated facts, whether paleontological or stratigraphical. On the other hand, it has been contended that no definite recognition of the Permian, even in the first-mentioned cases, ought to be made until after due consideration of all obtainable correlated palæontological and stratigraphical facts ; and not then, unless the preponderance of all that evidence should plainly favor such recognition.

The untenableness of the position indicated in the case first stated is shown by the facts mentioned in preceeding paragraphs of the occurrence in one and the same stratum of forms which have been held to be characteristic of separate geological periods, and even of separate ages. It is conspicuously shown in the case of the Texan formation, which is specially discussed in this article, be-

<sup>7</sup> These insects, however, have been by Scudder referred to the Trias, although they are associated with the most characteristic Permian flora that has yet been discovered on this continent.



cause both its Coal-measure and Triassic age can be even more readily proved, in an *ex parte* way, by special selections from its fossils, than its Permian age. And yet the sum of all the evidence is in favor of the latter.

The following paragraph from the work of Professors Wm. M. Fontaine and I. C. White tersely states<sup>8</sup> the principle which ought to govern the investigator in these cases, although it was written only with reference to the Permian character of the flora which they were then investigating.

"It is good evidence that we have to deal with a more recent formation, when we find it to show a decadence of old forms, and an introduction of new ones, destined to reach their culmination at a later period. Thus if we find, in a series of rocks, plants characteristic of the Carboniferous formation, and perceive that these die out, and disappear, we should not conclude from their mere presence that the age of the strata is Carboniferous, but rather that it is Permian. So also the finding of genera and species, even identical with those of the Trias or Jurassic, would not necessarily imply a Triassic or Jurassic age. If we find them to be exceedingly rare, their presence is rather indicative of a formation older than the Trias or the Jurassic. It is only by taking into consideration all the above named characters and other points which may be presented by the entire body of specimens, that we can determine the nature of the evidence offered by the life of a formation. It will not suffice to say arbitrarily that this or that feature is without value as evidence. Circumstances might reverse the normal relative weight of evidence from the several sources, and give preponderating weight to what would, if unaffected by them, have slight value."

Besides the observance of this principle, the investigator should remember the entire improbability that distinguishing types could have been simultaneously introduced in all parts of the world; and the no less evident fact that certain types in different parts of the world long survived their extinction in other parts. He should also bear in mind the now evident fact that the rate of progressive development of vertebrate, invertebrate and plant life respectively has not been uniform in all parts of the world. It therefore ought not to be expected that precisely the same associa-

<sup>8</sup>Permian or Upper Carb. Flora of West Virginia and S. W. Pennsylvania. Second Geol. Surv. Penn. Rep. Prog. P. P., pp. 109, 110.

tion of types would be found on this continent that occur in Europe and elsewhere.

Much difference of opinion has prevailed even among those who recognize the importance of considering all the facts which bear upon a given case of assumed equivalency. Some have believed that it should be strictly chronological as regards the whole of a given formation ; while others claim that the most we can reasonably assume in any case is approximate contemporaneity, and all that we can ever certainly know in such cases is the homotaxial relations of formations in different parts of the world respectively. The scope of this article, however, will admit of only a partial discussion of those views.

If all the time which is represented by the entire Carboniferous system in Europe is represented by the entire Carboniferous system of North America, the Permian of Europe must necessarily have a complete time equivalent somewhere on this continent. If that system is everywhere incomplete at the upper limit on this continent, and the same is complete in Europe, it necessarily follows that the stratigraphical time equivalent of the European Permian is either absent or incomplete in North America. But all the known facts which bear upon this case are of such doubtful value in their application to the question of strict chronological equivalency that it seems to be unprofitable to discuss it. Therefore the only question that remains to be considered in this connection is that of homotaxy.

The question, even after being reduced to these limits, is a complex one, for it still involves the consideration of conflicting and disagreeing palæontological evidence as well as a recognition of upper and lower delimiting boundaries of the formation. There can be no good reason for doubting that there are in various parts of North America strata which are homotaxially equivalent, at least in part, with the Permian of Europe. But it is equally true that much of the reputed North American Permian cannot be satisfactorily separated from the Coal-measures, and even those which have been separated more or less satisfactorily, are found to be so intimately related to the Coal-measures as to make the lower limit indefinable.<sup>9</sup>

<sup>9</sup> In view of the last mentioned condition, several American and European writers have applied the compromising term "Permo-Carboniferous" to that undefinable upper portion of the Carboniferous system. Unfortunately, however, some American authors have of late applied the same term to the whole Carbonif-

Heretofore it has been impracticable to say whether the upper limit of the Carboniferous system in North America is complete or not. For example, none of the reputed Triassic strata, which occur in various parts of the continent, have been found in such relation to the reputed Permian as to indicate that there was continuous sedimentation from the one formation to the other; nor have those Triassic strata been found to contain any conclusive palæontological evidence of their immediate succession to the Permian. Indeed, as regards the remains of invertebrate life, the existence of any Triassic strata in North America rests upon comparatively slight evidence: slighter, indeed, than it might have seemed to be before the discovery of Triassic types associated with well-known Carboniferous forms.<sup>10</sup>

The conflicting character of a part of the evidence afforded by the reputed North American Permian as to its age has already been shown, but there is an important case of want of harmony of different portions of certain accepted paleontological evidence that deserves mention. In Professor Cope's systematic catalogue of the Permian vertebrate fauna of North America,<sup>11</sup> he shows that it has been discovered mainly in two limited districts, one in eastern Illinois and the other in Texas. His catalogue also shows that of the 76 species enumerated, not one, and of the 32 genera only five, are common to the two districts. He also states that "the Permian vertebrate fauna of Illinois and Texas exhibits close parallels, but not yet generic identity on this continent."<sup>12</sup>

On the contrary, the marine invertebrates which characterize the North American Coal-measures, a part of which usually range up into the reputed Permian, are widely distributed on this continent,

erous series; seeming thereby to imply that the series includes an inseparable equivalent of the Permian, as well as the remainder of the system.

<sup>10</sup> The Triassic character of a part of the Permian fauna of Texas has been sufficiently stated, but it is also true that certain Carboniferous types occur in the Meekoceras beds of southeastern Idaho. Besides this, those beds appear to have an intimate stratigraphical relation with the characteristic Carboniferous strata beneath them. Add to these facts the further one that types similar to those which have been relied upon in referring the Idaho beds to the middle Trias, also occur in undisputed Carboniferous strata, and it seems possible that those reputed Triassic beds ought to be referred to the Permian rather than to the Trias.

<sup>11</sup> Trans. Am. Philos. Soc. vol. XVI, pp. 285-288.

<sup>12</sup> See Vol. III., Book I, U. S. Geol. Surv. Terr., p 25.

and their geographical range includes both the Illinois and Texan vertebrate localities. That is, the invertebrate fauna referred to is uniform over a region in which the vertebrate fauna is diverse.

In all the vertical and geographical range of these invertebrate fossils, there has never been observed any evidence of the decadence of old forms<sup>13</sup> such as would be taken to indicate an approaching close to the geological period which they have especially characterized; and it is only in the case of the Texan Permian that an introduction of new forms has been yet observed which might be regarded as forerunners of a new one.

Finally, while it is freely admitted that a considerable number of the invertebrate species which characterize the Permian of Europe have nearly related representatives on this continent, it should not be forgotten that they are as characteristic of our undisputed Coal-measures as of the reputed Permian. Even if those forms are really specifically identical on the two continents it does not necessarily prove the contemporaneity of the respective formations containing them. In fact those formations must be necessarily of a difference in age equal to the time required by the distribution of the species.

The recognition of the Permian of Texas as a separate upper group of strata belonging to the Carboniferous system is based upon both stratigraphical and palæontological evidence, and this evidence is fuller than that which has been adduced in favor of any other reputed Permian strata of North America. First, it contains invertebrate species which have been referred to the Permian in other districts to the northward, some of which are closely related to Permian species of Europe. Second, it contains the large vertebrate fauna published by Professor Cope, which he regards as characteristically Permian. Third, the Texan formation evidently constitutes an upper, apparently the uppermost, portion of the Carboniferous system. Fourth, the lithological difference between this formation as a whole and the Coal-measures beneath it

<sup>13</sup> It has been pointed out by some authors that certain of the brachiopods and other species which characterize the Coal-measures, have never been found in any of the reputed Permian strata, and it seems to have been assumed that their absence was due to a final decadence of those forms before the Permian period was reached. It seems, however, not at all unreasonable to infer that successive changes of conditions differently affected different classes of animals, in consequence of which the forms referred to were not extinguished, but only differently dispersed.

is sufficiently marked to make it conveniently distinguishable by the eye. Besides this, the mesozoic element which has been shown to exist among the invertebrates of the Permian of Texas may be properly regarded as holding an opposite relation to the Palæozoic element, and thus to suggest a balance of palæontological evidence in favor of the Permian age of that formation.<sup>14</sup>

The present state of our knowledge, or warranted opinion, as to the existence of the Permian formation in North America may be summed up briefly as follows :—

Although the two earlier groups of the Carboniferous system, namely, the Lower Carboniferous and Coal-measures are as clearly recognizable in the region traversed by the Mississippi river as they are in Europe, in many parts of this continent where Carboniferous strata are largely developed no distinctive recognition of either of those groups, or of the Permian, is practicable.

In those regions where the Coal-measures or their equivalent strata are recognizable, certain strata are sometimes found resting upon them which have been referred to the Permian; but those strata are as a rule, not distinctly separable from the Coal-measures upon either stratigraphical, or palæontological ground. That is, no distinct stratigraphical plane of demarkation between the Coal-measures and the reputed Permian is observable. Besides this, many of the common Coal-measure species range up into those Permian strata, and many acknowledged Permian types, according to the European standard, occur in the unquestioned Coal-measure strata beneath them.

The upper limit of the Carboniferous system and the lower limit of the Trias, have never been clearly recognized upon this continent, and it is therefore not yet known that either of these systems are here at any point complete in that respect. But the upper limit of the Carboniferous system is known to be incomplete at most places where strata of that age occur.

Notwithstanding the mezozoic character of some of the fossils found in the reputed or true Permian strata the relationship of all these strata, both palæontologically and stratigraphically, is far more intimate with the Carboniferous than with the Trias.

14. The value of this suggestion is somewhat lessened by the known presence of the *Ammonites parkeri* of Heilprin in the underlying Texan Coal-measures, and by the presence of similar types beneath the Permian in certain parts of the old world. Still, such forms as *Ptychites cumminsi* may properly be regarded as immediate harbingers of the Mesozoic age.

A large part of the North American strata which have been by various authors referred to the Permian have no valid claim to be either so considered, or as being separate from the upper Coal-measures. But a part of them may be reasonably assumed to be homotaxially equivalent with at least a part of the European Permian; although their delimitation from the Coal-measures may in most cases be difficult or impracticable.

The evidence upon which the Texan strata have been referred to the Permian is fuller than that which has been adduced with regard to any other North American strata, that have been so referred. That is, the evidence of both vertebrate and invertebrate fossils is in favor of such reference, and the difference in the character of the strata from those of the underlying Coal-measures, although not great, is conveniently distinguishable. Still, it is true that the Texan Permian strata bear many Coal-measure invertebrate species; and its flora is at present unknown.

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ON THE MAMMALIA OBTAINED BY  
THE NATURALIST EXPLORING EXPEDITION  
TO SOUTHERN BRAZIL.

BY E. D. COPE.

THE Naturalist Exploring Expedition left New York for Southern Brazil in the year 1882, and landed at Porto Alegre in the department of Rio Grande do Sul, with the object of making collections in that province.<sup>1</sup> It was under direction of Herbert H. Smith, whose former service under Prof. Frederick Hartt in the Geological Survey of Brazil, had given him ample acquaintance with the people and language. Regular collections were first made at the village of Sao Joao do Monte Negro, on a tributary of the Ura-

<sup>1</sup> Articles descriptive of this region by Mr. H. H. Smith will be found in the AMERICAN NATURALIST, 1883, pp. 480, 707 & 1007.